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Treatment of Knee Osteoarthritis in Relation to Hamstring and Quadriceps Strength

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Abstract. [Purpose] To assess the effect of hamstring and quadriceps strengthening exercises on pain intensity, gait velocity, maximum isometric strength, and activities of daily living of patients with knee osteoarthritis (OA). [Subjects and Methods] A total of 20 patients with knee OA, 50 to 65 years of age (57.65 ± 4.78 years), received hot packs, strengthening exercises for the quadriceps and the hamstring muscles and stretching exercises for hamstring muscles. Outcome measures included: the Western Ontario and McMaster Universities OA index questionnaire (WOMAC) scores for assessing health status and health outcomes of knee OA; self-reported pain intensity scores, measured using a visual analogue scale; the 50 ft walk test (a measure of gait velocity and function); and handheld dynamometry (a tool used to measure maximum isometric strength of knee extension and flexion). [Results] There was a significant difference between pre- and post-intervention measures of pain intensity, 50 ft walk times, hamstring strength, and quadriceps strength. Significant differences in WOMAC measures were also observed in the subscales of pain, stiffness and physical function, as well as WOMAC total scores. [Conclusion] Strengthening the hamstring muscles in addition to strengthening the quadriceps muscles proved to be beneficial for perceived knee pain, range of motion, and decreasing the limitation of functional performance of patients with knee OA.
Key words: Hamstring/quadriceps ratio, Knee pain, Osteoarthritis

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INTRODUCTION

Osteoarthritis (OA) is regarded a major public health problem, as reported by the World Health Organization. It is one of the major causes of impaired function that reduces quality of life (QOL) worldwide[1)]. OA is a very common disorder in patients presenting to primary care physicians in the Kingdom of Saudi Arabia, and is a leading cause of morbidity and reduced QOL[2)].

OA is a progressive degenerative disease that affects the joint cartilage, subchondral bone, and the synovial joint capsule. It has a multifactorial etiology and affects approximately 60% of individuals older than 50 years of age[3–5)].

The etiology of OA is related to repetitive mechanical loads and aging. Recent studies have separated the etiological factors into three main subgroups: sex, anatomy and body mass. The clinical manifestations are joint pain, stiffness, decreased range of joint movement, weakness of the quadriceps muscle and alterations in proprioception[6)]. Decreased strength in the muscle groups involving the joints is significant because it causes a progressive loss of function. These symptoms significantly restrict an individual's ability to get up from a chair, walk or climb stairs[7)]. Limping, poor alignment of the limb and instabilities can also be observed in individuals with OA. During movement, crepitation can be heard due to irregular joint surfaces caused by arthritis.

The knee is the most common weight-bearing joint affected by OA, with the disease predominantly affecting the medial compartment of the tibiofemoral joint[7, 8)]. Patients with knee OA frequently report symptoms of knee pain and stiffness as well as difficulty with activities of daily living such as walking, stair-climbing and housekeeping[3, 9)].

Plain radiographs are commonly used to classify OA subjects for the purposes of clinical studies, and joint space narrowing is often used as a measure of disease progression. Although plain radiography is currently the 'gold standard' for the evaluation of OA progression, it is associated with problems related to the accurate reproduction of measurements of joint space width, especially in subjects with knee OA[10)].

There is evidence that muscle dysfunction is involved in

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the pathogenesis of knee OA[2, 11]. Because the lower limb musculature is the natural brace of the knee joint, important muscle dysfunction may arise from either quadriceps weakness or weakness of the hamstrings relative to the quadriceps, which is usually assessed by the quadriceps: hamstring (Q:H) ratio[2, 12, 13]. Thus, evaluation of muscle dysfunction in relation to the knee joint should examine the strength of both the quadriceps and hamstring muscles as well as the balance of muscle strength[13].

Because there is no cure for OA, treatments currently focus on the management of symptoms. Pain relief, improved joint function and joint stability are the main goals of therapy. Studies conducted in recent years have provided data that support the hypothesis that muscle weakness and muscle atrophy contribute to the disease process[14]. Thus, rehabilitation and physiotherapy are often prescribed with the intention of alleviating pain and increasing mobility. However, because exercise must be performed on a regular basis to counteract muscle atrophy, continuous exercise programs are recommended for individuals with degenerative joint disease. Therapeutic exercise regimens either focus on muscle strengthening and stretching exercises, or on aerobic activities that may be land or water based.

Several muscle groups support the knee. The two main muscle groups that control knee movement and stability are the quadriceps and the hamstrings. The quadriceps and hamstring muscles have the potential to provide dynamic frontal plane knee stability because of their abduction and/or adduction moment arms[15]. Using a neuromuscular biomechanical model, the quadriceps and hamstring muscles not only have the potential to support frontal plane moments but also provide support to abduction-adduction moments[16].

In the frontal plane, balanced co-contraction of the quadriceps and hamstring muscles leads to increased joint compression, which should assist in knee joint stabilization[17]. The diminished co-activation of the quadriceps and hamstrings in women may contribute to greater knee joint instability in women than in men.

The strength relationship between the quadriceps femoris and hamstring muscles has been measured and reported by various researchers[18–21]. The isokinetic H:Q ratio for apparently healthy subjects has been reported to be 1.70:1 and 1.37:1 at 60°/s and 180°/s angular velocities of limb movement, respectively. The mean isometric Q:H ratio was found to be 1.43, a value below the ratio reported for young healthy adults (whose isometric Q:H ratio is 2:1); therefore, the Q:H ratio is different in OA due to the relatively greater weakness of the quadriceps femoris muscle[19, 22, 23].

The purpose of the present study was to assess the effect of hamstring and quadriceps strengthening exercises on the activities of daily living of patients with knee OA.

SUBJECTS AND METHODS

Subjects

Twenty patients with knee OA, 50 to 65 years of age, received hot packs and transcutaneous electrical nerve stimulation. They were assigned strengthening exercises for the quadriceps and hamstring muscles as well as stretching exercises for the hamstring muscles. Subjects diagnoses were based on both clinical and radiographic findings, and subjects had been referred by an orthopedic surgeon, general practitioner or consultant rheumatologist. Subjects exhibited knee pain of moderate or greater intensity for at least six months, knee crepitus, and restricted range of motion (ROM) and/or joint deformity of the knee. The present study was performed with the approval of the Ethics Committee of the Rehabilitation Medical Hospital, Medina and King Saud University, Riyadh, Saudi Arabia. A written consent form, signed by each participant, was obtained before beginning the study.

The present study was designed to investigate the effect of hamstring strength and quadriceps strength in the treatment of knee OA. The pretest and post-test measures, were: pain intensity, the Western Ontario and McMaster Universities OA index questionnaire (WOMAC) scores, ambulation activity and muscle strength.

Methods

All patients were tested before and after the 12-week treatment program. Patients received a hot pack, strengthening exercises for quadriceps and hamstring muscles, and stretching exercises for the hamstring muscles.

Measurement of physical function**:** The WOMAC index is a disease-specific, tri-dimensional, self-administered questionnaire used to assess health status and health outcomes of knee OA. The WOMAC consists of three subscales. The pain subscale has five questions regarding pain; the stiffness subscale has two questions regarding stiffness; and the physical function subscale has 17 questions regarding the degree of difficulty of physical function. Answers to each of the 24 questions are scored on five-point Likert scales (none=0, slight=1, moderate=2, severe=3, extreme=4), with total scores ranging from 0 to 96. Higher scores indicate greater disease severity. The WOMAC questionnaire is well recognized for its adequate validity, reliability and responsiveness for individuals with OA of the knee[24, 25].

Pain assessment**:** The visual analogue scale (VAS) is a self-reported measurement of pain intensity. The VAS consists of a horizontal line 10 cm in length. The line is anchored by the two extremes of pain: ‘No pain’ on the left and ‘Worst pain’ on the right[26, 27].

Measurement of ambulation activity**:** The 50 ft walk test is a measure of gait velocity and function. For this test, subjects were timed as they walked 25 feet, turned around and walked back to the starting position. Subjects were instructed to walk this distance as fast as they comfortably could without an assistive device. Time was measured using a chronometer[28, 29].

Assessment of isometric muscle strength**:** a handheld dynamometer is a tool used to measure maximum isometric strength of knee extension and flexion. There are two types of tests performed using hand-held dynamometers: ‘make tests’ and ‘break tests’. In ‘make tests’, the examiner holds the dynamometer stationary while the testee exerts a maximal force against it. In contrast, ‘break tests’ require the examiner to push against the testee’s limb until his or

Table 1. Pretreatment (Pre) and post-treatment (Post) measures of pain intensity, the 50-ft walk time, hamstring strength, and quadriceps strength

	Pain intensity (visual analogue scale)		50-foot walk test (seconds)		Hamstring strength (kg)		Quadriceps strength (kg)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean ± SD	7.1 ± 1.1	3.8 ± 1.3	14.3 ± 1.4	12.7 ± 1.6	39.3 ± 2.8	42.2 ± 2.8	43.1 ± 3.1	45.8 ± 3.7

Paired t-test showed that there were significant improvements between pre and post-test in measures of pain, the 50-ft walk time and hamstring strength ($p \leq 0.0001$)and quadriceps strength ($p \leq 0.001$).

Table 2. Pretreatment (Pre) and post-treatment (Post) measures of pain, stiffness, physical function, and total WOMAC scores

	Pain WOMAC		Stiffness		Physical function		WOMAC total scores	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean	10.2	5.5	4.0	1.9	34.6	22.8	48.8	30.3
SD	3.6	2.5	2.5	1.3	11.1	10.4	15.4	13.7

WOMAC: Western Ontario and McMaster Universities osteoarthritis index questionnaire
Paired t-test showed that there were significant improvements between pretreatment and post-treatment in WOMAC subscale scores of pain, stiffness and physical function as well as in the WOMAC total score.

her maximal muscular effort is overcome and the joint being tested gives way. Although both methods are reliable (‘make tests’ r=0.91, ‘break tests’ r=92)[30, 31], it is easier for an examiner to maintain the dynamometer stability while testing a strong person in ‘make tests’; therefore, ‘make tests’ were used in the present study to measure maximum the static voluntary force of the targeted muscle. Isometric quadriceps and hamstring muscle strengths were measured using a Nicholas hand-held dynamometer, which has an upper limit of 199.9 kg and measures force to the nearest one-tenth of a kilogram[32, 33].

The patients were assigned to a 12-week rehabilitation program of hot pack use and exercises. Treatment was given thrice weekly and the duration of the session was 45 minutes. Strengthening exercises for both the quadriceps and hamstring muscles was repeated 10 times during the sessions followed by the hamstring stretching program which involved 30 s hold and 30 s rest, repeated three times for three sets.

RESULTS

In the present study, 20 patients with knee OA participated in a physical therapy program involving a hot pack, strengthening exercises for quadriceps and hamstring muscles and stretching exercises for hamstring muscles. Their ages ranged between 50 and 65 years, with a mean age of 57.65 ± 4.78 years. Statistical analyses were performed using SPSS software version 11.0 (IBM Corporation, USA). The collected data were statistically analyzed and the mean and SD were calculated. A one-sample paired t test was used to compare pre- and post intervention measures with a confidence level of $p \leq 0.05$.

Significant improvements were observed in pain intensity (VAS), 50-foot walk test scores, hamstring strength and quadriceps strength (Table 1), and WOMAC scores also improved (Table 2).

DISCUSSION

OA of the knee is a major public health concern worldwide[13, 34], and one of the foremost causes of chronic disability in older adults[3, 13]. Preventive care is dependent on the identification of risk factors for the development of knee OA[13]. The symptoms are often associated with significant functional impairment, as well as signs and symptoms of inflammation including pain, stiffness and loss of mobility[35].

There is evidence that muscle dysfunction is involved in the pathogenesis of knee OA[2, 11]. Lower limb musculature is the natural brace of the knee joint[13], and recent research has indicated that improper alignment at the knee may originate proximally, and that poor force production secondary to muscle weakness may be a factor that ultimately causes stress on the knee[36–38]. Knee extensor and knee flexor strengths are both lost with the progress of symptomatic knee OA[39–41].

Muscle plays a major role in the structure and function of joints, as demonstrated by the disuse atrophy of the quadriceps femoris muscle that accompanies knee joint pain[42]. Weakness of the quadriceps muscle has been noted by the American Academy of Orthopedic Surgeons as a risk factor structural damage of the knee joint[22]. Muscle weakness affects the anteroposterior stability of the knee joint and makes patients feel unstable, leading to decreased personal confidence and decreased performance and independence in daily activities, causing disability and dysfunction in patients with knee OA[43].

The purpose of the present study was to investigate the importance of strengthening exercises for the hamstring

muscles in addition to the quadriceps muscles.

Knee OA affects the hamstring muscle more than the quadriceps muscle. Therefore, there is a need for physiotherapists, who have traditionally focused primarily on strengthening the quadriceps muscle of knee OA patients, to include hamstring strengthening in their management protocols. The ratio of the quadriceps to hamstring muscle strength is important for the stability of the knee and for protection from excessive stress[19, 22)].

In the present study, we found significance differences between pre-treatment and post-treatment measures of pain intensity (measured by VAS), the 50-ft walk test time, muscle strengths, and WOMAC scores. There was a significant difference between pre-treatment and post-treatment measures of pain due to the increase in the power of the quadriceps muscles and stretching of the hamstring muscles. This breaks down the cycle of pain by decreasing muscle spasm, increasing muscle strength and improving circulation, which decreases the concentration of metabolites. The increased power of the quadriceps muscles also improves ROM and functional performance. The improvement in ROM of knee extension occurs secondary to pain reduction, which is responsible for the improvement in muscle function. The improvement in ROM may be due to the influence of the stretching exercises, which increase muscle flexibility, leading to reduced muscle shortening, decreased pain and increased ROM. When maintained by strengthening exercises, this may lead to increased practice of activities of daily living and, therefore, improved functional performance.

The H: Q ratio has, until recently, been based on the concentric strength of these two muscle groups. Co-activation of these muscle groups is known to occur and takes place through opposing contraction modes. During leg extension, the quadriceps contract concentrically and the hamstrings contract eccentrically. Conversely, the hamstrings contract concentrically and the quadriceps eccentrically during leg flexion[44)].

Altered muscle coordination strategies in individuals with knee OA result in an increase in co-contraction of the quadriceps and hamstrings during walking. This may increase intersegmental joint contact force and facilitate disease progression[45)].

The quadriceps and hamstring muscles have the potential to provide dynamic frontal plane knee stability because of their abduction and/or adduction moment arms[15)]. Using a neuromuscular biomechanical model, Lloyd et al.[16)] noted that the quadriceps and hamstrings not only have the potential to support frontal-plane moments, but also provide support to abduction-adduction moments. Furthermore, they observed that these muscle groups appear to be capable of supporting up to 100% of the applied abduction-adduction loads.

Systematic reviews of conservative treatment have documented the effectiveness of exercise in reducing pain and disability due to knee OA[46–48)]. Evidence suggests that stretching and strengthening exercises decrease pain and improve muscular strength, functional ability and psychological well-being[49)]. Exercise increases muscle endurance, improves proprioceptive acuity and decreases arthrogenic muscle inhibition of the quadriceps[50)].

It is assumed that large external knee flexion moments require large knee extensor muscle forces to prevent collapse of the lower extremity during walking[45, 54)]. Large knee extensor muscle forces, in turn, would result in high joint compression forces[45, 55)]. In individuals with knee OA, a decrease in the external flexion moment has been reported and is believed to be a compensation strategy employed to reduce load on the knee joint[6, 45, 56–58)].

The strength relationship between the quadriceps femoris and hamstring muscles has been measured and reported by various researchers. The ratio of the quadriceps to hamstring muscle strength is important for the stability of the knee and for protection from excessive stress[22)]. The isotonic Q:H ratio is 3:2 for apparently healthy subjects and is known that this ratio is lower for OA patients.

Strengthening the hamstring muscle has been found to enhance the functional ability of a deficient knee[51, 52)]. This is likely due to the fact that, with an overall increase in both the hamstring and quadriceps strength, and the increase in the H:Q ratio, anterior-lateral subluxation of the tibia may be minimized[53)]. In our study we found significant improvements in the strengths of both the quadriceps and hamstring which would affect the H:Q ratio.

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